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VOLUME V

PROGRAM DEVELOPMENT PLAN

SYSTEM FOR UPPER ATMOSPHERIC SOUNDING (SUAS)

MARCH 1969

PREPARED UNDER CONTRACT NO. NAS1-7911 BY

BOOZ · ALLEN APPLIED RESEARCH Inc.

FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LANGLEY RESEARCH CENTER

FOR U.S. GOVERNMENT AGENCIES ONLY

NASA CR-66753-5

VOLUME V
PROGRAM DEVELOPMENT PLAN

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Booz, Allen Applied Research Inc.
4733 Bethesda Avenue
Bethesda, Maryland 20014

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FOREWORD

This study was conducted for the Langley Research Center of the National Aeronautics and Space Administration by Booz, Allen Applied Research Inc., Bethesda, Maryland under contract NAS1-7911. Mr. T.P. Wright, Jr., of the Flight Vehicles and Systems Division was the LRC Technical Representative of the Contracting Officer. The study was initiated on February 1, 1968 and completed on January 31, 1969.

The study was under the cognizance of Mr. C.F. Riley, Jr., Vice President, of Booz, Allen Applied Research Inc. Mr. W.E. Flowers, Research Director, was the Program Manager. Principal BAARINC staff contributors were Messrs. William E. Brockman, J. Frank Coneybear, Harry L. Crumpacker II, John L. Hain, and David W. Weiss. During the course of the study, Mr. Frederick F. Fischbach of the High Altitude Research Laboratory, University of Michigan, Mr. G. Harry Stine, a private consultant, and Dr. N. Engler, University of Dayton Research Institute, were engaged as consultants.

Reports produced as a result of this study are:

Volume I - Summary Report
Volume II - Technical Report
Volume III - Conceptual Design
Volume IV - Technology Development Plan
Volume V - Program Development Plan.

Volume I is an overview of the project listing results and conclusions.

Volume II is the complete report on the project containing all of the technical analysis.

Volume III is the conceptual design which details the recommended sounding system.

Volume IV is the Technology Development Plan which is an orderly description of the remaining technical problems that need to be resolved prior to system procurement.

Volume V is the Program Development Plan which is an overall plan for the implementation of the system for Upper Atmospheric Sounding.

PART I

SYSTEM FOR UPPER ATMOSPHERIC SOUNDING

1. SUMMARY

The objective of this project is the development of a cost-effective, upper atmospheric sounding system, which will produce synoptic, worldwide, wind and temperature/density data on the region between 30 and 100 km above the earth. The system is to be operational by 1976.

The Langley Research Center will be responsible for the Research and Development phase of this project. It is anticipated that the R&D phase will terminate with the establishment of one or several operational sites. The construction and long-term operational responsibility for the system will be assigned to an appropriate agency such as the Department of Commerce, Weather Bureau. The operational life of the system is to be a minimum of 10 years.

This program plan is presented to describe the R&D phase of the program in particular; however, in order to keep the entire program in perspective, a plan is presented for a 10-year operational program.

The mission of this system will require that every effort be made during R&D to introduce cost conscientiousness into each phase of the design. Constant attention will be directed toward cost/reliability/accuracy trade-offs.

The system consists of a rocket or rocket-boosted dart to launch a payload consisting of a 1-meter aluminized, inflatable sphere and 1 canister of chaff. The motion of the sphere and chaff will be tracked by an extremely accurate, phased-array radar to produce pressure/temperature/density data from 30 to about 100 kilometers and wind data from 30 to approximately 90 kilometers.

For purposes of developing costs, the current mission concept calls for 100 sites to launch 100 payloads per year, per site. The R&D costs can be placed in perspective when shown with overall system costs.

The Langley Research Center is involved in the R&D phase only. LRC will require a staff of about 10 professionals during R&D. R&D funding is estimated at about 25 million dollars to be expended over a 3-year period. The bulk of this research money will be spent on the development of the data acquisition/tracking system.

PART II

JUSTIFICATION, RELATED WORK AND HISTORY

2. INTRODUCTION

The need to understand the phenomena of the upper atmosphere—nominally 30 to 100 kilometers—stems from two basic requirements. First, it is desirable, if not mandatory, to understand the causes and and effects of perturbations about the normal or standard atmosphere models. The knowledge of these phenomena will contribute to our understanding of the behavior of this body of air and will contribute to better understanding of satellite decay velocities, reentry trajectory investigations, hazardous material dispersion and diffusion characteristics, erosion of satellites due to particulates in the atmosphere, behavior of gravity waves and their effect on communication due to movement of the ionization layers, and numerous other areas. The second requirement consists of the establishment of relationship between upper atmospheric phenomenon and surface conditions. These relationships, if they exist, will provide a means for more accurate global and local weather prediction. Long-range weather modification programs will also benefit from such a bank of knowledge.

Various government agencies have specific operational mission for upper atmospheric soundings (30/100 km). These missions range from the prediction of the magnitude and distribution of nuclear fallout from weapons or satellite burnup, to synoptic analysis of the 5.0, 2.0 and 0.4 millibar layers. A properly configured sounding network of the type advanced in this project will meet most existing operational requirements, with the advantages concomitant with single agency management.

Meteorological soundings of the upper atmosphere are now fairly commonplace. A great number of sensing techniques have been tested and a number of launch techniques developed through past experimentation and the operation of current networks.

2.1 UPPER ATMOSPHERIC SOUNDING

Sounding of the upper atmosphere began around 1950. Figure II-1, a record of launchings by the Meteorological Rocket Network (MRN), shows the dramatic increase in the number of soundings in the last decade. In 1959, a total of 38 launches were reported by the MRN from 4 participating sites. In 1967, 3,567 meteorological soundings were reported from 30 participating sites. Since its inception, the MRN has recorded over 10,000 MET launches (reference 2).

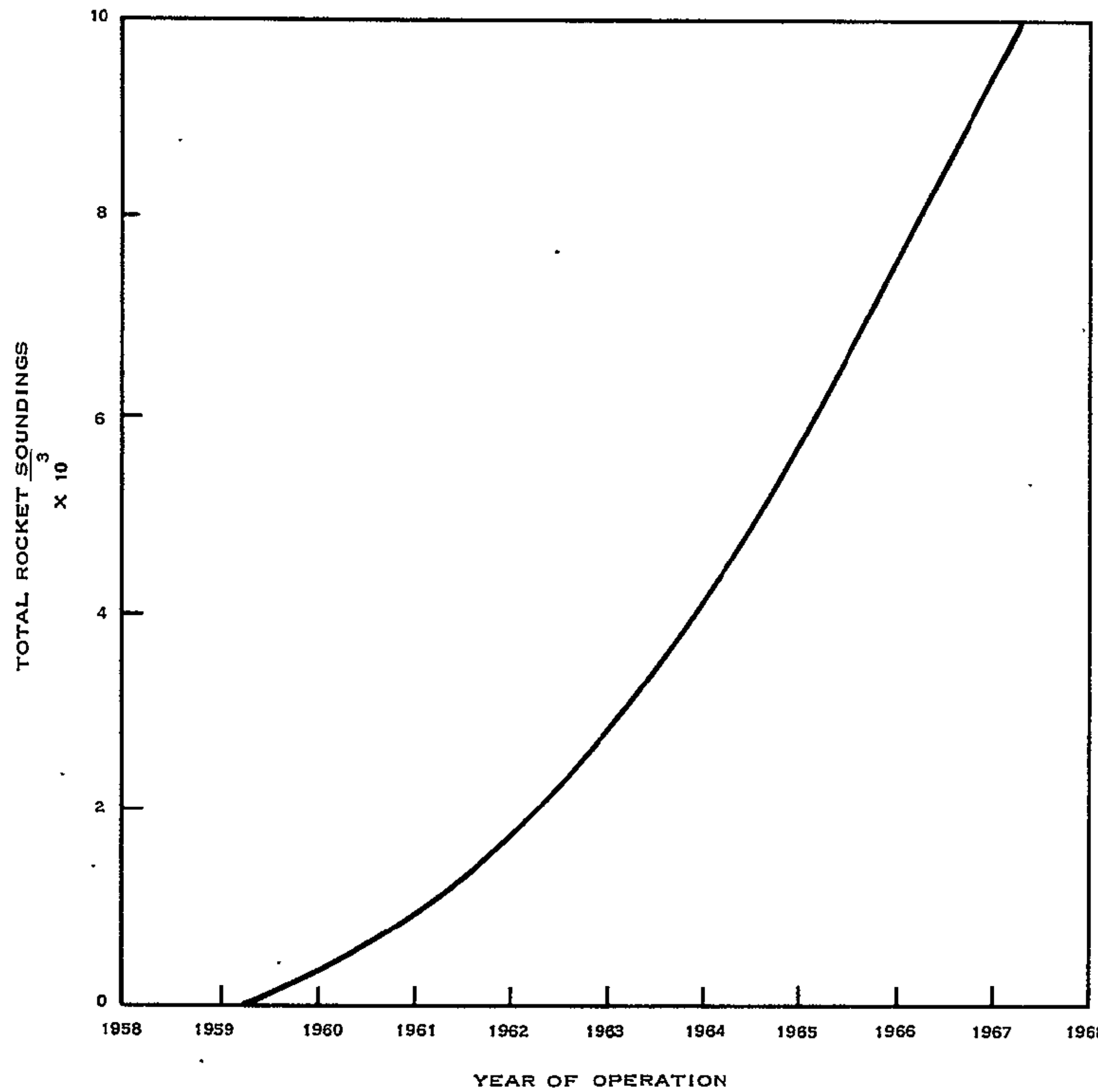

Figure II-1. Rocket Soundings Reported by the Meteorological Rocket Network

The majority of these launches reached altitudes of 60 to 70 km. For example, in 1967, 90 percent of the launchings reached that altitude. Soundings were concentrated at altitudes below 70 km because of the cost of launch vehicles for higher altitudes, and because physical and chemical changes occur at around 70 km which make accurate measurements, above 70 km, very difficult.*

The meteorological operating funding estimates for Fiscal Year 1967, 1968, and 1969 are presented in Table II-1. About 5 million dollars is budgeted for Rocket Sounding during 1969 (reference 3). These estimates include funding from all operating agencies of the government. The sounding rocket portion of the budget has consistently been about 5 percent of the total.

Table II-2 is a listing of the cost of launching most of the current operational rocket systems. It includes both the rocket motor and

*Density decreases with altitude. At around 70 km, conventional sensors (such as thermistors) cannot be used to make accurate measurements. At altitudes above 70 km, the molecules of air are subject to molecular dissociation and diffusive separation. The mean molecular weight which is considered constant to about 80 km, decreases with altitude above 80 km. For altitudes in this region and above, new and novel techniques are required; none of which have been used on an synoptic basis.

Table II-1
Meteorological Operating Funding Estimate
(thousands of dollars)

MEASUREMENT TECHNIQUE	1967	1968	1969
SURFACE	25,600	26,557	27,050
BALLOON	26,900	31,935	33,297
ROCKET	6,300	4,994	4,938
AIRCRAFT	17,500	23,281	22,944
RADAR	8,000	9,063	7,158
SATELLITE	22,300	23,966	23,472
TOTALS	106,600	119,796	118,859

Table II-2*
1967 Meteorological Rocket Launches
and Expendable Costs

VEHICLE	HARDWARE COST (VEHICLE/PAYLOAD)	NUMBER OF FLIGHTS
ARCAS	2,000	1,949
ARCAS-SIDEWINDER	3,500	22
ARCAS-SPARROW	5,500	24
BOOSTED DART (CHAFF)	750	30
BOOSTED DART (INSTRUMENTED)	950	17
BOOSTED DART (SPHERE)	600	11
CAJUN-DART (CHAFF)	2,100	63
HIGH ALTITUDE DART	3,000	25
JUDI-DART (CHAFF)	435	120
LOKI	1,000	1,270
NIKE-CAJUN (SPHERE)	7,200	5
NIKE-CAJUN (VAPOR TRAIL)	9,300	16
RAVEN	2,000	15

*Based on reference 3.

the payload. The average cost is $1,755. The cost for flights to 70 km averaged $1,600 (3,475 of the 3,567 launches were to about 70 km or below).

The early launches, through 1963, primarily reported winds. These measurements were made by ground-tracking chaff released at high altitude (reference 2). Since 1963, temperature, density, and constituent measurements have been made. By 1966, about two-thirds of the rocket soundings measured temperature and wind, whereas in 1963, less than one-fifth of the soundings measured both (reference 2).

The number of launch sites is expanding, providing wide, geographic distribution of measurements. The original launch sites were at the established missile test ranges such as White Sands, Cape Kennedy, and Wallops Island.

2.2 CURRENT METEOROLOGICAL ROCKET NETWORKS

Two organizations are in existence which schedule rocket launches and collate the resulting data. One additional organization acts as a clearinghouse and storage location for meteorological data.

The two sounding organizations are the Meteorological Rocket Network (MRN) and the Experimental Inter-American Meteorological Rocket Network (EXAMETNET). The organization which collects and distributes the results of the launches is the World Data Center A for Meteorology. Both networks maintain a sounding schedule for participating sites, but will utilize results from other soundings.

2.2.1 METEOROLOGICAL ROCKET NETWORK (MRN)

The Meteorological Rocket Network (MRN) was formed in late 1959 in order to continue the synoptic atmospheric program initiated during the International Geophysical Year, which ended in 1959 (reference 4). It was formed as a part of the meteorological working group of the Inter-Range Instrumentation Group of the Range Commander's Council and initially consisted of only the major rocket ranges in the United States (reference 5). The network has established launching schedules for participating sites, so that synoptic data is regularly collected. There are currently 18 operational launch sites, within the Meteorological Rocket Network (Table II-3).

The missions of the MRN are to (1) set launching schedules for synoptic data collection and (2) establish a common data format, and to collect, reduce, and disseminate data from each launching. The training, launching, experimentation and development of experiment

Table II-3
Currently Active MRN Rocket Launch Sites

		AGENCY
1.	Thule, Greenland	DOD
2.	Ft. Greely, Alaska	DOD
3.	Ft. Churchill, Canada	DOD
4.	Cold Lake, Canada	DOD
5.	Point Mugu, California	DOD
6.	White Sands, New Mexico	DOD
7.	Eglin Air Force Base, Florida	DOD
8.	Wallops Island, Virginia	DOD
9.	Ascension Island	DOD
10.	Barking Sands, Hawaii	DOD
11.	Cape Kennedy, Florida	DOD
12.	Grand Turk, Bahamas	DOD
13.	Eniwetok	DOD
14.	Antigua, BWI	DOD
15.	Panama, Canal Zone	DOD/AEC
16.	San Nicolas Island	DOD
17.	Ship Wheeling, PMR	DOD
18.	West Garnish, Scotland	U.K.

packages are all functions of the individual agencies and firing ranges that are included within the Network. The data is made available and is used by all of the experimenters and scientists that are connected with the Network.

The launch vehicle, the tracking equipment, the payload and the telemetry function are provided by the Parent organization of the different launch sites included within the Network. A large number of different systems are in use. The accuracy and completeness of the data varies considerably from launch to launch (reference 2). About ten different tracking radars are in regular use, the most powerful of which is the FPS-16 or its derivatives. Standard launch vehicles are Arcas, Loki-dart, Judi-dart, 5-inch, 7-inch, and 16-inch guns and a number of rockets of foreign manufacture. The payloads include chaff, inflatable spheres, and a variety of parachute/telemetry packages.

A typical "model" of the components of a launch site of the MRN are presented in Table II-4. Generally, a radar track of wind velocities and a telemetered temperature trace is recorded. Storage facilities vary noticeably, depending, to some extent, on the climate at the site. The launch crew also varies in number and composition depending on the types of activities conducted at the station.

Table II-4
Typical Components of a Meteorological
Rocket Network Launch Site

FIXED FACILITIES

Rocket Launcher

Launch Control Building

Intercommunications and Range
Safety Equipment

Radar Tracking and Plotting Equipment

GMD-Type Data Acquisition System

Auxiliary Power Unit

Optical Tracking Device

Wind Measuring Equipment

Payload Preparation Equipment and Shop

Storage Facility

Land Area (including improvements) or Ocean Range

Operation Crew of 10 Men

EXPENDABLES

Rocket (including squibs)

Payload (thermistor transmitter)
and Parachute

Because of the wide variation in equipment and in the activities, other than meteorology that occur on site, it is practically impossible to determine the costs involved in each launch operation. Currently, the cost which is used is that of the rocket and payload, which is about $2, 000 for the Arcas and Arcasonde 1A purchased in quantities of about 100. This cost, however, should be used carefully, because it does not include any of the other expenses of the launch, such as crew salaries, tracking,and telemetry equipment, capital investment in the launch site, etc. The real cost of the launch should be expected to be much more than the cost of expendables.

The launch sites included in the MRN are presented in Figure II-2. A total of 37 stations have participated, though only 18 are currently active (Table II-3).

2.2.2. EXPERIMENTAL INTER-AMERICAN METEOROLOGICAL ROCKET NETWORK (EXAMETNET)

The Experimental Inter-American Meteorological Rocket Network (EXAMETNET) was founded in August of 1965 through an agreement between the space agencies of Brazil, Argentina and the United States. It was established through memoranda of understanding between the various space agencies involved. The purpose of

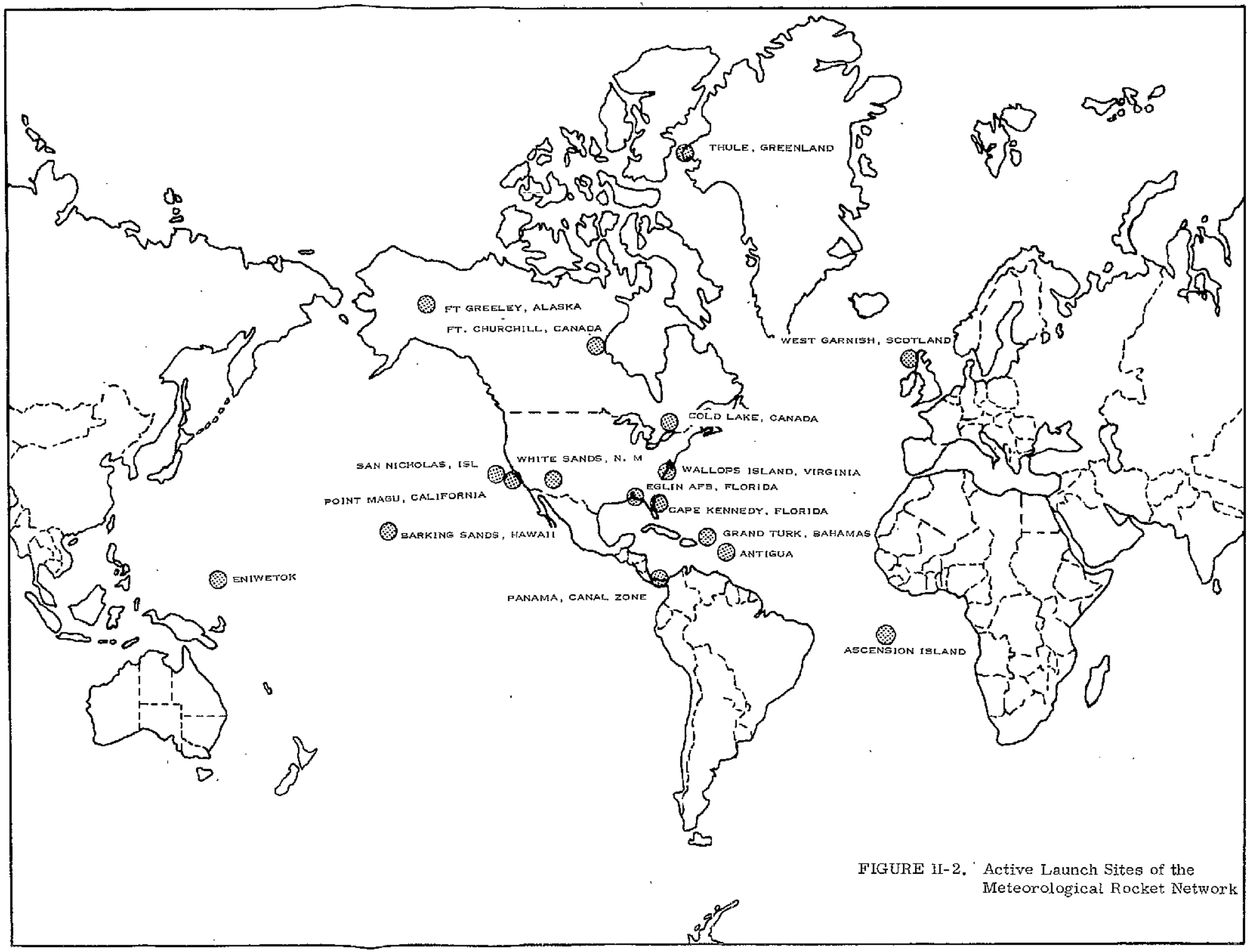

FIGURE II-2. Active Launch Sites of the Meteorological Rocket Network

EXAMETNET is to contribute to studies of atmospheric structure and behavior in the Southern Hemisphere and to help explain differences and similarities between the Northern and Southern Hemispheres (reference 6). Each of the countries involved provides personnel and facilities and has other distinct responsibilities within the organization.

The EXAMETNET operation includes the establishment of synoptic launching schedules, personnel training, data collection, data analysis, and dissemination, (reference 7), the development and coordination of experiments and the transportation of vehicles and payloads. A launching schedule has been established which is synoptic and which coordinates with the sounding schedule of the Meteorological Rocket Network. All training for technical and professional personnel is conducted at Wallops Station. The training course is 16 to 18 weeks long and trains the 7-men launch crews both in the classroom and in actual launches.

The format for the exchange of data between the participating countries has been standardized. Part of the raw data is sent to all of the participants on a semi-real-time basis. All of the raw data is sent to Wallops Island where it is reduced and disseminated to the participants.

The basic sounding system currently in use consists of a dart-rocket vehicle, a combination telemetry-receiver decoder, and a MPS-19 radar with an OA-626 computer. The primary payload consists of a WOX-1A thermistor and transmitter and a radar-reflective parachute. Both temperature and wind data are obtained. The Arcas rocket vehicle is also used, to some extent, in this network.

The construction and operation of launch sites within a country, is paid for by that country, with the exception of ground-based radars and some telemetry equipment which is on loan from the United States.

The typical "model" of the components of a launch site of the EXAMETNET is presented in Table II-5. Again, it is practically impossible to determine the actual total launch costs. The cost of expendables, the dart rocket and payload, is about $1,000.

Currently, three sites are operational within EXAMETNET. These are Wallops Island in the United States, Machiquita in Argentina, and Natal in Brazil. It is planned to expand the number of sites to include two more sites in each of the South American countries plus a site in the Antarctic. Expansion in the more distant future may include Lima, Peru; Puerto and Angel, Mexico; and several North American sites.

Table II-5
Typical Components of an Experimental
Inter-American Meteorological Network Launch Site

FIXED INVESTMENT

- Loki Launcher
- Blockhouse
- Intercommunications and Range Safety Equipment
- MPS-10 Radar
- OA 626 Computer
- Telemetry Receiver-Recorder and Antenna
- Wind Measuring Equipment
- 40 KW Power Unit
- MK 51 Optical Director
- Storage Facility
- Payload Preparation Equipment
- Land Area (including improvements) or Ocean Launch Range

Launch Crew* of 7 Men (2 on radar, 2 on computer, 1 range safety, 1 payload and 1 vehicle technician)

EXPENDABLES

- Loki dart rocket
- WOX-1A sonde (thermistor and transmitter) and Parachute

TRANSPORTATION

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*Crew support facilities not included.

2.2.3 WORLD DATA CENTER A FOR METEOROLOGY

The World Data Center A for Meteorology was established in 1957 as a central storage, collation, and distribution point for meteorological data. It is under the cognizance of the Committee on Space Research (COSPAR) of the International Union of Geodesy and Geophysics. It is collocated with the National Meteorological Data Center (ESSA) in Asheville, North Carolina. The center includes data from balloons as well as sounding rockets. It does not handle data from satellites or experimental soundings, using large rockets (such as the Grenade experiments).

The World Data Center is in the final stages of preparation of a new international format for meteorological rocket data. It is hoped that the format, which has been approved by COSPAR, will be adopted early in 1969.

2.3 GENERAL SOUNDING SYSTEM REQUIREMENTS

The fundamental requirement for continued expansion of the upper atmosphere research activities is the development of a low-cost, efficient sounding system which measures temperature/density and wind vector data. The system must be developed for routine synoptic

soundings on an operational basis. The system must utilize common sensors to assure data uniformity and must be a fully coordinated activity. In order to obtain the necessary synoptic and high-resolution data (for wave structure analysis), a large number of launches must be made from many sites. The sites, to be fully effective, should be located on the basis of data requirements, and not be limited to existing sites. Such a system, developed and operated within a reasonable budget, is an important extension of the existing meteorological system.

2.4 RELATED WORK

Several related programs are underway which bear on this program.

2.4.1 SENSORS

In the United States many agencies are active in sensor development: notable are the NASA; Air Force Cambridge Research Center; Naval Ordnance Laboratory, White Oak, Maryland; Army Signal Corps, Fort Monmouth, New Jersey; White Sands Missile Range, New Mexico; and the Weather Bureau. These agencies and others are contributing contract and grant monies to assist universities and private corporations in sensor development as well as to

maintain in-house programs. This list is not meant to be exhaustive, as many other organizations are similarly involved.

Pertinent sensor development is being carried out in Canada, India, Japan, Australia, and France, although it is not expected that these developments will have a substantial impact on the present program.

2.4.2 LAUNCH VEHICLES

The situation in launch vehicles closely parallels the sensor situation.

In the United States, the same agencies concerned with sensors are engaged in supporting launch vehicle investigations and development. In the case of launch vehicles, internal company funding for development is routine. The rocket producers have been active in the meteorological rocket field for some time. A relatively complete line of rockets is currently available as a result of many development programs. When viewed from the synoptic sounding standpoint, an emphasis on cost and falling mass hazard reduction are the most important consideration in recent development, since performance and reliability have been reasonably demonstrated.

Foreign nations actively pursuing meteorological rocket development are Japan, India, Canada, Australia, France, West Germany, Argentina, Mexico and Brazil. Little is reported from the Soviet bloc nations.

2.4.3 TRACKING

The tracking of meteorological rockets has been accomplished primarily by missile-tracking radars which are available at the launch site. Active payloads (transponders) have been tracked with sufficient accuracy to produce reliable data while those payloads dependent upon passive tracking for primary data have often produced unreliable data. Generally speaking, extensive tracking systems have not been developed for the express purpose of tracking meteorological experiments.

Phased-array tracking development within the Air Force has many features in common with requirements recommended for a meteorological vehicle tracker. The requirements for a suitable tracking system for the sphere and chaff have received intensive investigation in this study and of the total development cost of the SUAS of approximately $25 million, the tracking system will require approximately $22 million.

2.4.4 WORK RELATED TO THIS CONCEPT

A partial list of relevant current development programs are:

Payload:

Sphere construction techniques - Schjeldahl Co.

Sphere ejection techniques - University of Michigan

Sphere drag coefficient research - Sandia Corp.

Sphere data reduction techniques - University of Dayton

Sphere data reduction techniques - University of Michigan

Sphere-chaff, dart payload - Naval Ordnance Laboratory, White Oak

Chaff techniques - White Sands Missile Range

Rocketry:

140 km meteorological rocket - Aerojet

Meteorological rocket - Thiokol Astro-Met

Rocket - U.S. Army Missile Command/Canadian Armament Research & Development Establishment/ Langley Research Center

Falling mass hazard elimination - U.S. Army Missile Command/Langley Research Center

Falling mass hazard elimination - Thiokol Astro-Met

Tracking:

Phased-array development - General Electric

Phased-array development - RCA.

2.5 BRIEF PROJECT HISTORY

This Langley Research Center Small Meteorological Sounding System Program was initiated in June of 1964, with the submission of the "Technical Plan for the Development of a Small Meteorological Sounding Rocket System."

The stated objective was to develop a cost-effective data gathering system for obtaining meteorological data on a synoptic basis, to an altitude of approximately 100 kilometers.

The program was, in essence, broken down into three main areas of concentration.

The first being to improve reliability of selected existing meteorological systems primarily through modification of the payload components.

The second being the development of an intermediate vehicle, of up to 70 kilometers in altitude, using state-of-the-art concepts.

And the third area of concentration was the development of a complete sounding system and would be fully responsive to the overall program objective.

It is in fulfillment of this third area of concentration that this Program Development Plan is addressed.

2.5.1 CONCEPTUAL DESIGN

During the month of February 1968, a contract was awarded to Booz, Allen Applied Research Inc. for a study to pursue the third objective above.

This contract was for a study to be performed that would produce a conceptual design of a sounding system for use in the upper atmosphere, on a worldwide basis. Of primary concern, was the proper identification of the sensor technology development potential, as this was considered to be the pacing item of the entire study.

The recommendation, by the contractor, of the Conceptual Design felt to have the greatest merit, was formally presented to LRC during the month of October 1968.

A summary of this recommended Conceptual Design and the associated Technical Development requirements, are contained in this document.[1]

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1 A complete Conceptual Design document and a Technology Development Plan are presented under separate covers.

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7. The Experimental Inter-American Meteorological Rocket Network, "EXAMETNET Data Preparation and Guidance Procedures Manual," NASA, Wallops Station, January 1968.

PART III

TECHNICAL PLAN

3. DESCRIPTION

3.1 OBJECTIVE

The objective of this program is to develop a system which will provide synoptic upper atmospheric meteorological data on a world-wide basis.

3.2 NATURE OF THE PROJECT

Existing, operational meteorological systems produce data on the atmosphere and its motions from ground level to about 30 km. The proposed system will concentrate on the region from 30 km to about 100 km, and is designed to be used in conjunction with the existing systems. The system presented in this Project Development Plan is the result of an exhaustive review of current and projected technology and a Systems Design including a cost/technical trade-off analysis of competing subsystems. This system consists of a launch vehicle and launcher, a payload, a data acquisition/tracking system and associated ground support equipment.

The launch vehicle will loft a payload to an altitude of about 130 km at apogee. The payload contains a 1-meter diameter, aluminized, 1/2 mil mylar, inflated sphere, and about 1 pound of .0006-inch diameter, aluminized plastic filaments or "chaff." The interactions of the sphere and chaff, with the ambient density and winds encountered on its otherwise ballistic-trajectory, are measured by an extremely accurate, phased-array tracker/data acquisition system located at the launch site. These measurements will be recorded by the tracking system and will be processed at the launch site (probably) to yield density, pressure, temperature, and horizontal wind vector profiles of the atmosphere between altitudes of 30 km and about 100 km. This system will be operated in conjunction with conventional systems such as the rawinsondes to produce complete coverage from ground to 100 km.

The research program presented in this document supports a concept which consists of 100 launch sites, each to fire about 100 rockets annually. The construction and operation of these sites will be handled by an appropriate agency such as the Department of Commerce. The deployment of the sites and actual firing rate need further investigation.

3.3 TECHNICAL DESCRIPTION

3.3.1 PAYLOAD

The payload subsystem consists of a 1-meter, inflatable sphere and a package of radar reflective chaff, together with an aerodynamically designed container and a means of ejecting the sphere and chaff from the container at a predetermined time.

3.3.1.1 SPHERE

The sphere and chaff are to be tracked by the tracking subsystem and position data recorded. By processing the position data and developing velocities and accelerations along vertical and horizontal axes, the sphere position data is converted to ambient density and wind. The density is derived from the equation for aerodynamic drag:

$$D = \frac{1}{2} C_D A \rho V^2$$

D = drag

C_D = coefficient of drag

A = area

V = velocity

m = mass

ρ = density

Drag is derived from the drag acceleration equation.

$$ma_D = D$$

a_D = drag acceleration

thus:

$$a_d = \frac{1}{2} C_D \rho V^2 \left(\frac{A}{m}\right)$$

and

$$\rho = \frac{2a_d}{C_D V^2} \left(\frac{m}{A}\right)$$

Temperature can be computed if density is known using the equations of state and of hydrostatic pressure.

$$T_z = \frac{1}{\rho_z} \left[\left(\frac{M}{R}\right) \int_{z_o}^{z} - \rho g dz + \rho_o T_o \right]$$

where

T_z = ambient temperature
z = altitude
z_o = starting altitude
M = gram molecular weight
R = universal gas constant
g = acceleration of gravity
ρ_o = ambient density at z_o
T_o = ambient temperature at z_o

typical, the integration of density proceeds downward from the starting altitude z_o, which is the altitude of highest valid density data.

the measured drag acceleration will be small and difficult to determine from position data. To increase the altitude potential of the system, it is desirable to design the sphere with an $\frac{A}{m}$ as large as possible and to have the velocity in any region as high as practical.

The foregoing considerations have resulted in a substantial effort on the part of experimentors to determine drag coefficients of spheres with great accuracy, to construct spheres from very light material such as .0005-inch thick mylar, and to develop techniques to loft the sphere to an apogee well above the region of interest so that the sphere will have a high velocity during the measurement period. Radar reflective coatings are deposited on the mylar to facilitate tracking.

Due to the nature of tracking subsystems, range data is more precise than angular data. Because of this, more accurate measurements can be made in the most critical accuracy regimes (near the upper altitude limit of measurement) by tracking sphere positions on ascent rather than descent. If the vehicle launcher and tracking subsystem are physically adjacent, as is usually the case, then ascending data will be mainly range measurements while descending data will have substantial angular components.

In order to track the sphere on the ascent leg of the trajectory, it must be deployed just before entering the critical measurement region. If it is deployed early, drag will prevent the sphere from attaining the desired apogee and if too late, the region of interest will be missed.

Ejection and inflation of a very fragile plastic sphere from an aerodynamiclly-heated container traveling at great velocity through the atmosphere is a difficult design problem, but one that has been largely overcome. Forward ejection of the sphere on the upleg is apt to result in a puncturing of the sphere by the rocket or a rocket component. Rearward or sidewise ejection is indicated.

Inflation will probably be (and is on existing designs) by means of a liquid chemical which vaporizes immediately upon exposure to low pressure. The liquid is contained in a small pressurized vessel within the packaged sphere. The acceleration imparted to the sphere by ejection is utilized to puncture the vessel and allow vaporization (and inflation) to occur.

Ejection will probably be by means of a black powder charge ignited by a dry-cell—timer—squib combination. Detonation of the

charge drives the packaged sphere rearward through the payload housing into the atmosphere where inflation occurs. A sabot, which surrounds the sphere, is often used to protect the packaged sphere from aerodynamic heating, hot ejection gas, and ejection friction.

3.3.1.2 CHAFF

Chaff is designed with an $\frac{A}{m}$ ratio as large as possible for the same reasons that dictated a high $\frac{A}{m}$ ratio for the sphere. Chaff can be manufactured in the shape of very fine filaments (.001 inch or less) or thin flat ribbons. In either case, the surface must be coated with an electrical conductor or the chaff material must be an electrical conductor, to permit radar tracking. The length of the chaff is made to correspond with a dipole length of the radar frequency. Chaff can be made with an $\frac{A}{m}$ ratio about one order of magnitude greater than that of an unflated sphere; therefore, it has a potential for measuring atmospheric motion higher in the atmosphere than a sphere. There are many drawbacks with the use of chaff. Since the individual pieces have random orientations, the chaff falls with different drag accelerations and eventually the "cloud" disperses into a column. When tracked with a radar device, the exact position of the cloud is difficult to determine because the size and shape of the target is not predictable

and is ever changing. As a result of the tracking difficulty, precise double differentiation of position data is impossible. The random orientation makes assignment of an accurate drag coefficient impossible. For these two reasons, chaff is not used to determine density. The determination of high-altitude winds, however, over a vertical layer of considerable size, is feasible with chaff. The favorable $\frac{A}{m}$ ratio causes the chaff to experience more displacement due to horizontal winds than that attainable by a sphere. This fact permits winds to be measured to a greater altitude than the sphere, given the same tracking capability.

Chaff will be ejected from the payload container near apogee with sufficient force to separate the individual pieces into a cloud but not enough to disperse the cloud into an imperceptible radar target. Ejection will be accomplished under (essentially) vacuum conditions. The optimum ejection technique for this application must be developed experimentally.

3.3.2 LAUNCH VEHICLE

Many candidate vehicles are available which are capable of placing the small payload at an apogee of 130 to 140 km. Analysis of performance and cost projections has shown that a rocket or a

rocket-boosted dart have a cost advantage over competing launch concepts. The rocket system is a long-burning rocket motor. Burnout occurs sufficiently high that drag is unimportant for the remainder of the flight. The rocket-boosted dart system employs a high-thrust, short-burning rocket booster with a low-drag, detachable payload container (or dart) which coasts to apogee. The cost trade-offs between the two systems are close and the choice should be decided in a competition between manufacturers.

3.3.2.1 THE ROCKET SYSTEM DESIGN GOALS

The long-burning rocket will have an impulse requirement on the order of 40,000 lb/sec. Launch acceleration is about 15 g which makes the vehicle wind-sensitive. A higher launch acceleration may be required to overcome wind-loading. It could be provided by a detachable booster or a short-burning propellant grain added to the main motor (dual thrust). The rocket is expected to be about 6 inches in diameter, 8 feet long and weigh about 150 pounds. Fins are required for stability. They must be able to withstand appropriate levels of aerodynamic loading and atmospheric heating. Spin must be regulated to prevent roll-pitch coupling. Stability is a problem because of the large rocket and small, light payload; ballast may be required.

3.3.2.2 THE ROCKET-BOOSTED DART SYSTEM DESIGN GOALS

The rocket-boosted dart system consists of a high-thrust, short-burning rocket with a total impulse in the neighborhood of 41,000 lb/sec. The booster is expected to be slightly larger in size than the slow-burning rocket motor. The dart will be 2 inches in diameter and 4 to 5 feet in length. It will have a payload volume of approximately 100 cubic inches. Fins will be required for both the booster and the dart. The payload will require ballast. Acceleration levels with this system will be in the neighborhood of 50 g.

Aerodynamic heating of all critical surfaces, (e.g., payload container, fins), will be controlled by the application of ablative material. Fin-leading edges may require structural reinforcement by high-melting point metal such as inconel.

3.3.3 LAUNCH SUBSYSTEM

The requirements of the launcher are straightforward and designs are plentiful. The launcher must be trainable in azimuth and elevation for wind corrections if a low acceleration (15 g) launch is the case. A boosted dart with 50 g acceleration might also require some launcher adjustment. The launcher should facilitate ground-level loading and

be capable of trouble-free erection to a nominal elevation of 85 degrees. About 10 feet of rail guidance should be provided. Less rail or zero-length launch may be allowed for a boosted dart.

The launcher cannot be designed until after the rocket design is made, and launcher constraints should play no important part in the vehicle design.

3.3.4 DATA ACQUISITION/TRACKING SYSTEM

The basic requirement for the data acquisition/tracking system is to develop a position versus time profile for the chaff and the sphere.

The data acquisition/tracking system will look like the block diagram shown in Figure III-1. The heart of the subsystem is a general-purpose digital computer. Upon receipt of a lift-off signal from the launcher, the computer will command the transmit array to illuminate a sector to intercept the ascending vehicle at a predetermined altitude. The pulse repetition rate will be set to permit unambiguous ranging on the reflected signal. Simultaneously, a cluster of receiving beams will be formed in the same sector. Automatic angle tracking of the vehicle will be initiated when a predetermined number of sequential receiver pulses cross the 10 db threshold.

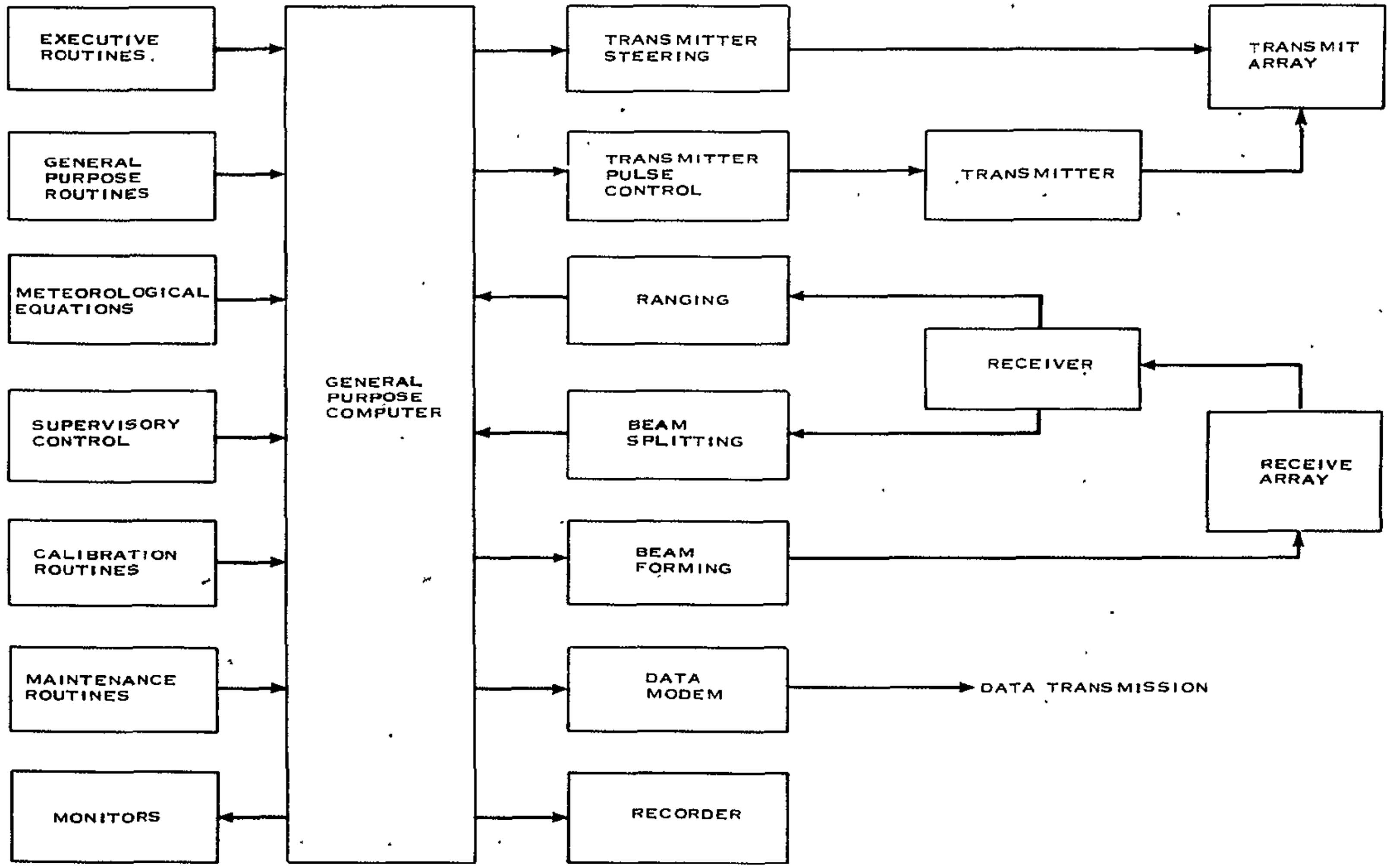

Figure III-1. Data Acquisition/Tracking System

Ejection and inflation of the sphere will produce two targets exhibiting markedly different reflective characteristics. A pair of displays will permit the operator to select the one corresponding to the sphere, and range tracking (along with velocity determination) will be initiated.

The computer will continue to steer the transmitted beam in such a direction as to keep the sphere illuminated. It will simultaneously form a monopulse quad beam at the receiver to ascertain the instantaneous line-of-sight to the sphere. Beam-splitting techniques will be used to increase the angular resolution by 20:1. The interval between pulses will be gradually increased as the range increases to ensure nonambiguous readings. As the sphere velocity becomes very low, the redundancy in readings will become considerably in excess of that which is useful in achieving requisite accuracy in density profile and wind vectors, so the pulse spacing may be increased.

The system will simultaneously track the ascending vehicle until the release of chaff. The chaff will be tracked like the sphere. The phased-array tracker will be housed in a one-story building* with the planar antenna lying flat on the roof. A tilt of the roof equal to that of the launcher's nominal inclination will be required. The arrays

---

* This building will also house the all-support equipment and personnel.

themselves will be solid-state, integrated circuit units assembled on automated assembly lines. The transmitter units will include the final power amplifier, the steering elements, and the radiating elements. The receiving units will include the radiating elements, the low-noise receiver front ends, and the beam-forming matrices. The range tracker will be an early-gate/late-gate, solid-state digital tracker with doppler determination.

The circuitry lends itself to mass production techniques. Complete subassembly and checkout will be conducted in the factory. The on-site activity will be limited to installation, plug-in, and calibration. The design will include full maintenance and calibration routines under computer program control so as to permit operation and maintenance by personnel of minimal skills.

The most critical part of the tracker is the receiving array. It will contain about 10, 000 identical elements packaged into convenient modular subassemblies.

The phased-array tracker offers two inherent advantages over an electromechanical tracker. Acquisition is far less of a problem since scan patterns may be implemented in microseconds in lieu of

seconds, and multiple target tracking is much more readily attained. Both characteristics are useful in the synthesis of this sounding system. The facile acquisition capability minimizes the need for skilled operating personnel and the need for backup vehicles. The multiple target tracking capability eases the transfer of track from the aerodynamic vehicle to the inflated sphere, thus, further minimizing the need for skilled operators and backup vehicles.

3.3.5 ASSOCIATED SYSTEMS

There are no physically associated systems. The associated functional systems are:

(a) Utilization of launch operating site personnel for routine balloonsonde operations in conjunction with the rocket operations.

(b) Data reduction in whole or in part by the computer capability of the tracker.

(c) Communication system to transmit data to the data analysis center.

(d) Logistic system for rockets, payloads, and personnel requirements.

(e) Safety or search systems depending on the ultimate design and its falling mass hazard implications.

Little elaboration of these systems is necessary. Most interfaces can be solved by straightforward management techniques.

3.4 TECHNICAL DESIGN PARAMETERS

3.4.1 PAYLOAD

Sphere:

Reliable inflation to spherical shape within 2% on any diameter

Sufficient overpressure to remain spherical from a vacuum to 10 mb external pressure for 10 minutes

Diameter not less than 1 meter

Weigh not more than 150 grams including inflation gas.

Radar reflecting aluminized surface

Packaging dimensions: maximum diameter 38 mm
maximum length 46 cm.

Chaff:

Plastic filaments with radar reflective coating not to exceed .0006 in diameter. Alternative: Rectangular shaped, radar reflective coating on 2 surfaces, not to exceed .0006 inches in one dimension and .0048 inches in the other. Cut to S-band dipole length $\pm$ 1 mm.

Material not to exceed density of 1.5 gms/cc

Packaging dimensions: same as sphere

Weight: not less than 450 gms.

Operations:

Sphere to be ejected at preset time of
$\pm$ 1 second.

Sphere to be ejected at 30 meters/second $\pm$ 5 m/s

Sphere to be ejected rearward or to the side with no mechanical part to be directly aft of the sphere

Chaff to be ejected at preset time of
$\pm$ 5 seconds.

Chaff orientation to be essentially undisturbed by ejection technique

Ejection mechanisms not to exceed 1 kg and 200 cc.

Environment:

Storage of packaged payload for 1 year

Any items requiring assembly to be done by 1 man in less than 30 minutes

Storage conditions: Dry, -40° C to +50°C

Package to be fully operative to -70°C

Linear acceleration not to exceed 150 g's

Transportation and vibration limits to typical MIL Specs

Payload to be fully operative after 5 minutes in any vacuum since ejection and inflation will occur in a near vacuum.

3.4.2 ROCKET AND PAYLOAD CONTAINER

Performance:

At effective launch angle of 85°Q. E., place payload at an apogee of not less than 130 km nor more than 150 km.(from sea level launch).

Linear acceleration not to exceed 135 g's

Interior surface of payload container not to exceed 70° C

Apogee performance not to deviate from design specification more than $1\sigma = 5$ km.

Launch acceleration not less than 15 g's

Payload container to remain aligned with tangent to trajectory within 10° to 85 km.

Environment:

Storage for 2 years at -40° C to +50° C.

Transportation and vibration typical MIL Specs

Reliable operation at -40° C to +50° C. (May be conditioned for optimum performance.)

3.4.3 LAUNCHER

Performance:

Provide rail guidance for 9 feet of travel

Deflect less than 1° in launch elevation plane and cross plane under 200-pound load at tip of rail

Adjust readily up to $\pm$ 85° in elevation and $\pm$ 45° in azimuth.

Provide for underside loading of launch rail in horizontal position of no more than 5 feet above ground.

Elevate from horizontal to 85° Q.E. in less than 1 minute.

Operation from -40°C to +50°C (special equipment may be provided for cold weather operation).

Environment:

Operate without regard to rain, snow, and icing conditions or other adverse climatic conditions.

3.4.4 DATA ACQUISITION/TRACKING SYSTEM

Performance:

Tracking - Multiple (1-5) targets tracked simultaneously, acquisition of rocket before separation (20 square meter target at 5 km), all targets within same 20° cone of total coverage.

Accuracy - $\pm$ 0.1 milliradian angular, $\pm$ 5 meters range (1σ values, $\pm$ 20% of boresight, 1 hit, 160 km range, data rate of 1 point per 2 milliseconds, 1 square meter target).

Range = 200 km maximum

Coverage = 60° cone around a fixed boresight

Operation = All-weather, minimum technical attendance.

Characteristics:

S-band, phased-array, one face

High-duty cycle - ~40 percent

Prepackaged for simple on-site installation with minimum checkout and test

Solid-state, modular automatic fault isolation for plug-in maintenance

Built-in, general-purpose digital computer

Initial on-site calibration may require appreciable use of equipment and personnel

Routine calibration fully automated.

3.5 APPROACH TO DEVELOPMENT

The major portion of the effort will be directed toward the development of a suitable, accurate, cost-effective data acquisition/tracking device. The immediate requirement is for the preparation of a precise procurement specification which is substantiated by a comprehensive analysis. This is necessary to insure that the system delivered will meet requirements. This effort is described first; the remainder of the development effort is directed toward satisfying design requirements in the other system areas.

3.5.1 DATA ACQUISITION AND TRACKING SYSTEM

A cost-effective, data acquisition and tracking system is the major development task associated with the sounding system. Figure III-2 is an illustration of the approach to be used for this development.

3.5.1.1 COMPLETE SITE OPERATION PLAN

Develop a detailed functional plan of the complete launch event. This plan will show all steps associated with the launch event, properly time-phased, including preparation, the launch itself, the measurements cycle, all data collection and reduction, shutdown and refurbishment.

3.5.1.2 REVIEW PHASED-ARRAY DEVELOPMENT

A detailed study of applicable phased-array development projects (Air Force and Navy) as applied to this system to determine the optimum final configuration; one that will take advantage of developed circuitry, software, manufacturing techniques, etc. This study will define the current distribution of operational tasks between hardware, software and operators. It will identify any restrictions as to the physical location or arrangement of equipment.

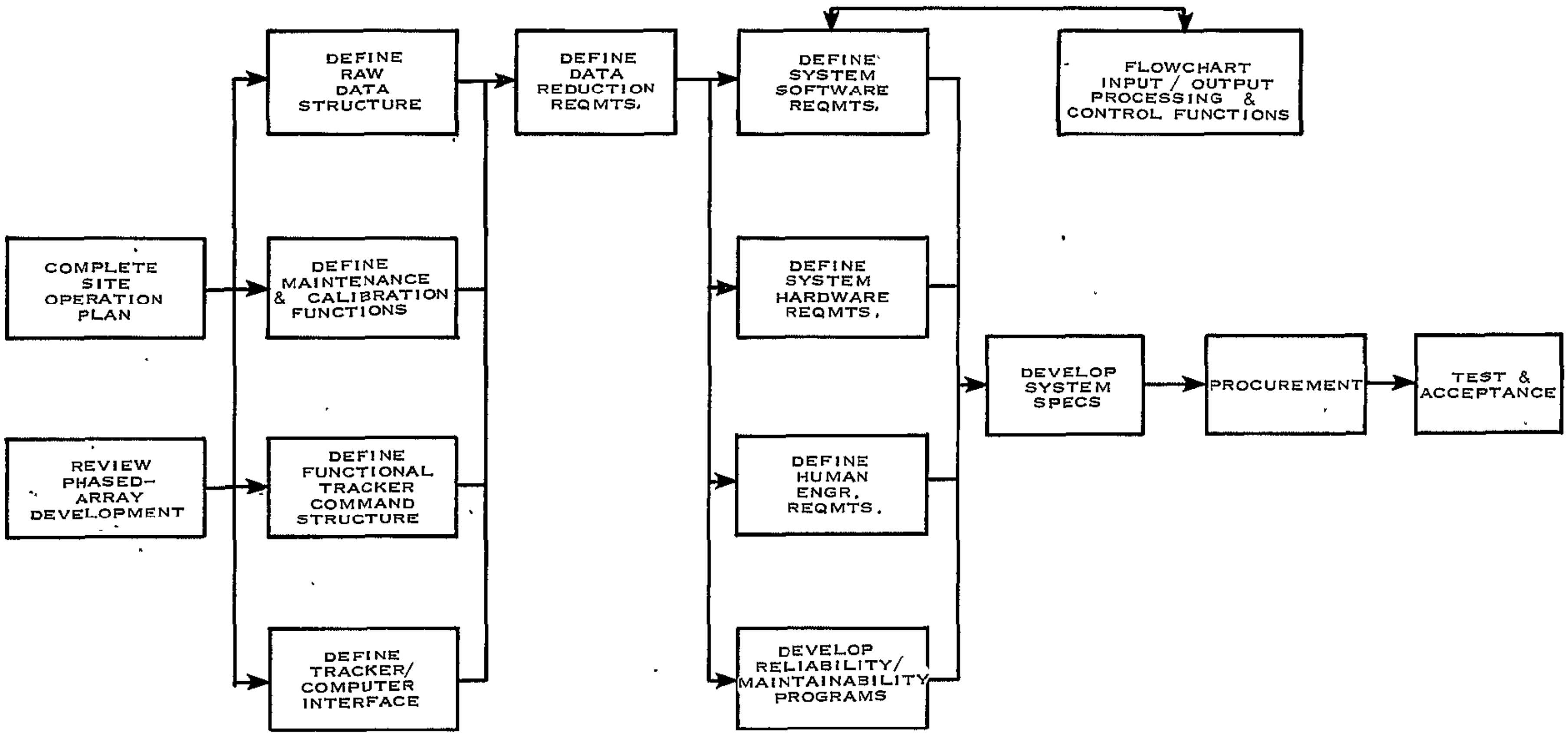

Figure III-2. Tracking and Data Acquisition System Development Plan

3.5.1.3 DEFINE RAW DATA STRUCTURE

A detailed examination of the measurement trajectory to define the form and structure of the time/position trace developed by the tracker.

3.5.1.4 DEFINE MAINTENANCE AND CALIBRATION FUNCTION

Define the overall maintenance and calibration requirement for the Data Acquisition/Tracking system.

3.5.1.5 DEFINE THE FUNCTIONAL TRACKER COMMAND STRUCTURE

Develop the tracker command requirements to perform acquisition and track under computer control.

3.5.1.6 DEFINE THE TRACKER/COMPUTER INTERFACE

Develop a functional specification of the Tracker/Computer interface.

3.5.1.7 DEFINE DATA REDUCTION REQUIREMENTS

Develop the optimum method of wind/temperature/density inference from the time/position trace developed during tracking.

3.5.1.8 DEFINE SYSTEM SOFTWARE REQUIREMENTS

Develop the computer inputs, outputs, control functions and processing requirements. These requirements have been tentatively grouped into 7 categories:

(a) Executive routines

(b) General-purpose routines

(c) Meteorological routines

(d) Supervisory control

(e) Calibration routines

(f) Maintenance routines

(g) System monitor routines.

This effort should result in functional flowcharts of the software system.

3.5.1.9 DEFINE SYSTEM HARDWARE REQUIREMENTS

Develop a functional description of the hardware required by the Data Acquisition/Tracking system.

3.5.1.10 DEFINE HUMAN ENGINEERING REQUIREMENTS

Develop the human factors to be employed in the design to make the system as self-sufficient as practical, and to function smoothly with the level of operator personnel anticipated on site.

3.5.1.11 <u>DEVELOP RELIABILITY PROGRAM</u>

This step should be accomplished in concert with the overall reliability/maintainability program for the entire site. A single project should be initiated to establish the reliability/maintainability philosophy for the sounding system in order to conduct trade-offs of cost/reliability/effectiveness across the entire system, and execute a uniform reliability/maintainability program throughout the R&D phase.

3.5.1.12 <u>DEVELOP SYSTEM SPECIFICATION</u>

Develop a procurement specification which will insure that (1) every technical requirement of the system will be met by the developed product, (2) no qualified manufacturer will be excluded from bidding due to unnecessary hardware restrictions, and (3) manufacturers will be encouraged to exercise their ingenuity in design and manufacturing to produce the best product for the lowest price.

3.5.1.13 <u>PROCUREMENT</u>

Procurement will be accomplished in the standard fashion, based on a detailed set of functional specifications.

3.5.1.14 ACCEPTANCE TESTING

Develop a comprehensive set of acceptance tests for the system to insure that each system meets requirements.

3.5.2 APPROACH TO OTHER TECHNICAL PROBLEMS

Other problems:

(a) Motor development - A detailed design study should produce a motor design for an optimum booster-dart combination and an optimum long-burning motor. These designs must be optimized on the basis of present technology. Specific impulse, burning time, and propellant mixtures must not be projected beyond those having passed static tests. Competitive bids will be sought afterward.

(b) Payload Ejection - Develop a mechanism which will eject the sphere at the proper time followed by a chaff ejection many seconds later. Sphere ejection must be preset and be reliable within ± 1 second. The sphere and the chaff must also be ejected at a specified velocity.

(c) Dart Development - A prototype of the dart design should be built and ground tested. After satisfactorily passing

ground tests, the dart payload should be flight tested on a suitable current operational rocket.

(d) Sphere Drag Coefficient - A sphere drag coefficient research project should be conducted. This program is urgent and has current applications to other programs. The way the program is managed is as vital as the research results because of the scientific implications. The testing should consist of:

Subsonic ballistic sphere firings and

Supersonic ballistic sphere firings.

(e) Sphere Fabrication - A design study to develop optimum sphere fabrication techniques consistent with anticipated production volumes. This study should also optimize inflation and packaging techniques.

(f) Site Design Specification - A design requirements study should be conducted to develop a design criteria document which specifies the launch site to a level of detail sufficient for an architect to design specific plans once sites are selected.

(g) Synoptic System Design - The present effort has concentrated on the technical requirements for the system. A study should now be initiated which defines:

> The network in terms of minimum grid spacing, optimum grid spacing, domestic system and worldwide system requirements. This study should also document all possible, available government sites, and should show the trade-off in using these sites as opposed to unrestricted site selection.
>
> Data analysis and handling - a study which details the optimum method of density, temperature and wind data inference given the tracking time/location trace, and where this data reduction can best be accomplished (field site or central facility).
>
> Network Communications - a study to determine the communications required by the network based on data volumes, etc.
>
> System Management - develop an operational plan for the system including all aspects from the field sites to overall network control.

(h) Falling Mass Hazard (FMH) - This problem should be approached from several standpoints:

> The effect that current rocket and dart technology will have on launch site selection and grid spacing.
>
> Trade-off study between rocket and dart systems from the FMH standpoint.

PART IV

RELIABILITY & QUALITY ASSURANCE PROVISIONS

4. INTRODUCTION

This section describes reliability and quality assurance provisions for the Meteorological Sounding System project for Langley Research Center (LRC). These provisions are based on the NASA reliability publication NPC 250-1, and the NASA quality publications NPC 200-2, NPC 200-3, and NPC 200-1A.

4.1 QUALITY ASSURANCE

All production and prototype hardware for the Meteorological Sounding System will be built under the quality requirements of NPC 200-2. Ground equipment for the Meteorological Sounding System will be built under the requirements of NPC 200-3.

The contractors and major subcontractors will be required to generate and implement a LRC-approved quality assurance program plan to carefully control the transition of each system from design to hardware. These plans will detail the methods of control over processes, procedures, specifications, parts and materials usage;

nonconformance and failure actions; design changes; testing; operator training, fabrication methods and techniques; calibration of equipment; in-process monitoring; receiving, inspection, and storage; source inspection requirements; and other quality assurance activities. These plans will further outline the methods of positive participation by each contractor project office in assuring the adequacy of its quality program plan.

The Meteorological Sounding System project office, upon recommendation from the LRC Quality Assurance Branch, will approve all quality program plans and will monitor their implementation through the project reliability manager and the assisting government inspection agencies.

4.2 GOVERNMENT INSPECTION AGENCIES (GIA)

The project will make use of the NASA/DOD government inspection agency agreement to provide on-site monitoring of contractor implementation of the respective quality program plans. In general, on-site monitoring activities will be delegated to on-site government agencies at the contractor, associate contractor, and major subcontractor level. Source inspection of major or critical suppliers will be provided through these on-site agencies. In all cases, the

requirements for such GIA activities will be established by the Meteorological Sounding System project manager at LRC. Direction and guidance of GIA activities will be provided by the reliability manager or his designated representative.

4.3 RELIABILITY

Controlling documents for reliability assurance on the project will be NPC 250-1. In general, system and associate contractors will comply with the requirements of NPC 250-1. Major subcontractors will comply to the extent jointly determined by the purchasing contractor and NASA.

The prime contractor, and each associate contractor, will be required to generate and implement an LRC-approved reliability program plan to ensure the design and development of an inherently reliable system, the establishment and accomplishment of an adequate test program, and the satisfactory solution of problem areas affecting reliability in the hardware phase of the program. The subcontractor activity will be covered in the procuring contractor's plan.

Each reliability program will stress simplicity, selection and use of space-qualified parts and materials (as appropriate). Reliability

will be continually assessed at the subsystem and functional levels in terms of redundancy trade-offs, failure mode, effect, and criticality analyses, and comparative modeling, together with the incorporation of an adequate testing program throughout the design, development, qualification, and flight phases of the program. These plans include the methods used by each project team to control and direct the reliability program to ensure the adequate accomplishment and the delivery of reliable systems.

The Meteorological Sounding System project office will approve all reliability program plans, and will monitor their implementation through the project office and through the project reliability manager, with the assistance of an independent reliability assessment contractor.

4.4 INDEPENDENT RELIABILITY ASSESSMENT

The project may make use of an independent reliability assessment contractor to provide NASA with continuing appraisal of the reliability of the design being developed by the contractors and major subcontractors. The reliability assessment contractor will receive direction and guidance from the project reliability manager. Assessment activities will include review of contractor reliability and quality plans, parts programs, preferred practices, and reliability

assessments, in addition to continuing independent design assessment. The reliability assessment contractor will also provide the project manager with technical assistance in determining reliability goals for the program, and in solution of particular design problems.

The reliability assessment contractor will obtain technical materials (and data necessary for accomplishing these reliability assessments) from the contractors and principal subcontractors and NASA. The assessment contractor will define inputs needed for each phase of the reliability assessment (design, development, test).

PART V

MANAGEMENT PLAN

5. ASSIGNMENT OF MANAGEMENT RESPONSIBILITIES

The assignment of management responsibilities for the System for Upper Atmospheric Soundings (SUAS) project has been made in strict accordance with NASA General Management Instruction 4-1-1, revised March 8, 1963, "Planning and Implementation of NASA Projects." The attachments to the Management Instruction have been a adapted to the SUAS project to serve as the primary definition of project responsibilities.

5.1 OVERALL MANAGEMENT RESPONSIBILITY

The Associate Administrator for Space Science and Applications is responsible for the overall direction and evaluation of the SUAS project. He has delegated to the Director, Office of Space Science and Applications, the authority to direct the Langley Research Center (LRC) in the execution of the project as described herein.

The Director, Space Applications has designated ______________ to be Program Manager for the SUAS Project. He will be the primary point of contact in Headquarters for all matters relating to the project.

5.2 PROJECT MANAGEMENT

The Langley Research Center will be responsible for the accomplishment of the SUAS project, and will serve as the Project Management Center with the following broad responsibilities.

5.2.1 FOR PROJECT MANAGEMENT

Integrate the several systems of Project SUAS, carrying out such overall systems engineering activities as may be necessary.

Ensure that oversights and omissions in any respect of the project are detected and corrected in time to minimize cost overruns, schedule delays, and technical failures.

Identify project requirements not anticipated in the SUAS Project Development Plan and actively take such steps as may be necessary to obtain solutions to these needs.

5.2.2 FOR SYSTEMS MANAGEMENT

Undertake and complete the technical design, fabrication, testing, site selection/development and operation of the SUAS systems through the R&D phase:

(a) Launch Vehicle System (including launcher and payload)

(b) Tracking and Data System

(c) Support Facilities System.

5.3 SPECIFIC FUNCTIONS AND AUTHORITY

It is proposed that the Director, LRC, within his designated authority to conduct the activities of his center, will designate a project manager to carry out the following functions for the overall management of the SUAS project.

5.3.1 PROJECT-WIDE PLANNING AND EVALUATION

Initiate and submit for Headquarters' approval Project Development Plan (PDP) changes which are necessary to revise the technical parameters or the scheduled dates of accomplishment of the SUAS project.

Maintain continuous surveillance of scheduled milestones for all systems in terms of programmed costs, technical reliability and completion dates.

Devise technical or procedural changes in areas within his own authority, or recommend such changes to higher authority.

Ensure that adequate and timely coordination, reporting and liaison is implemented and maintained between LRC, NASA and other centers or agencies, as appropriate.

5.3.2 SYSTEMS INTEGRATION, PROJECT-WIDE SYSTEMS ENGINEERING AND SCHEDULING

Maintain surveillance over the quality of systems engineering for any of the project systems to ensure a maximum probability that the several systems will effectively perform their part of the project assignment.

Decide interface questions concerning the interrelationships of the systems which make up the SUAS Project.

Assign tasks within the LRC with respect to the successful integration of the various systems, modifying the schedule of launch vehicle, tracking and data acquisition system and support facilities systems without affecting major milestones in the SUAS PDP.

Submit for Headquarters' approval proposed changes in scheduling of scientific or technical scope which go beyond the currently approved PDP.

5.3.3 TECHNICAL CONSULTING AND ADVICE

Establish such ad hoc advisory bodies as may be appropriate.

Request from appropriate parts of NASA such special technical information as may be required.

5.3.4 BUDGET REQUIREMENTS AND FINANCIAL OPERATING PLANS

Submit initial budget recommendations for the project, or any part of its system, to the Director, LRC, as part of the annual revisions budget preparation, and such revisions on a case by case basis as may be required.

5.3.5 FINANCIAL MANAGEMENT

Make decisions, within the approved financial operating plans or other limitations by Headquarters or the LRC Director, to commit or to reprogram funds as necessary for the achievement of project assignments within the LRC.

Arrange with the approval of the Director, LRC, for the financing of special unbudgeted requirements and studies concerned with overall systems integration, systems engineering or reliability.

5.3.6 CONTRACTING ACTIVITIES

Ensure that LRC or other NASA elements maintain appropriate technical monitoring over the quality, timing and cost of work placed with outside contractors or other Government agencies.

Provide close liaison with, and assistance to, procurement officials in their negotiation and administration of the contracts for the project.

Request such status reports as appear appropriate from LRC for all SUAS contracts.

Serve as chairman or member on the following system contractor selection boards:

(a) Launch and Vehicle System Contractor Selection Board

(b) Support Facilities System Contractor Selection Board

(c) Tracking and Data System Contractor Selection Board.

5.3.7 REPORTS

Develop and initiate project reports required by NASA or by project circumstances to keep the project manager, the system managers, and higher authorities informed of project progress.

Furnish project reports to Headquarters and field centers as established in the PDP.

Ensure that data resulting from the project are disseminated in accordance with the provisions of the PDP.

5.3.8 AUTHORITY LIMITATIONS

Authority delegated herein shall be exercised in accordance with applicable laws and regulations.

5.4 PROJECT MANAGEMENT ORGANIZATION

The Langley Research Center will assign project responsibility to the appropriate Division. A Project Manager will be assigned at the proper time.

The project organization is shown in Figures V-1 and V-2. The Project Manager reports directly to the Chief of his Division.

The design development, fabrication, testing, production deployment and field support of the project will be divided between the LRC and supporting contractors.

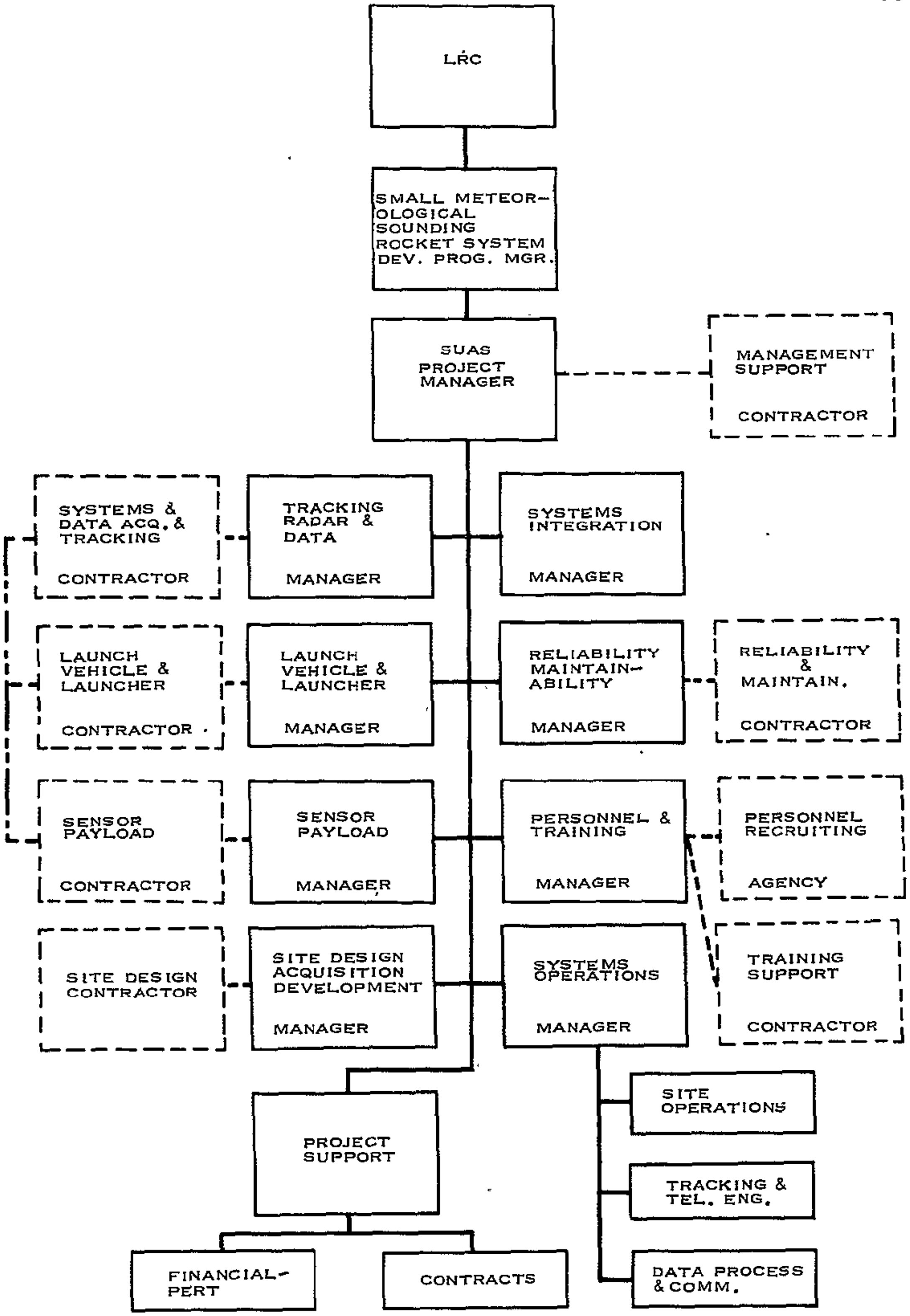

Figure V-1. SUAS Project Contractor Support

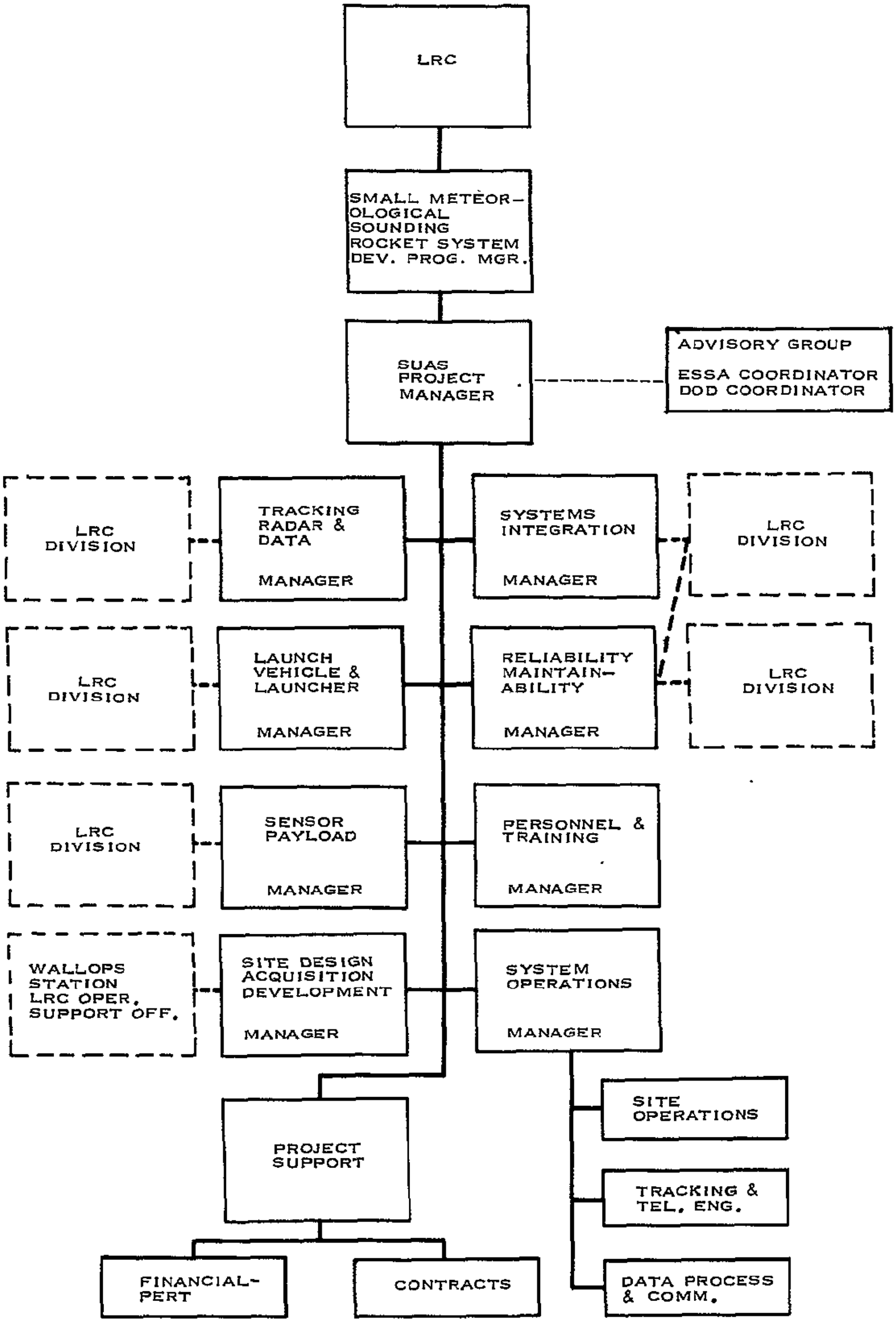

Figure V-2. SUAS Project LRC Support

5.4.1 TECHNICAL SUPPORT

Support to the Project Manager in performing the Center work will be provided by various Center organizations according to the administrative or technical discipline involved. Specific individuals from the organizations involved are noted on Figure V-2. These organizations and the key personnel are assigned responsibility for ensuring that the tasks are properly executed. For purposes of managing this project, responsibilities for support in the technical areas will be assigned as follows:

(a) Tracking and Data Acquisition:

(b) Vehicle and Launcher:

(c) Payload:

(d) Launch Facilities:

(e) System Reliability and Quality Assurance:

(f) Systems Integration:

(g) General Range Support: Wallops Station and the LRC Operations Support Office at Wallops Station.

5.4.2 ADMINISTRATIVE SUPPORT

In accordance with the usual LRC project management practice, support activities in scheduling and financial areas are as follows:

(a) The program scheduling and analysis unit will provide services in use of the NASA/PERT and companion Cost System as a management control tool.

(b) Assistance in management and control of funds will be provided by the Program Control Analysis and Budget Office and the Fiscal Division.

(c) Assistance in contract support will be provided by the Procurement Division.

(d) Financial Control is exercised by Center management in that all procurements and any changes in scope must be approved by designated line authorities.

PART VI

REVIEW AND REPORTING

6. REVIEW AND REPORTING PROCEDURE

6.1 PROJECT REVIEW

The SUAS Project will use a review and reporting system that is based on procedures used in successful execution of projects of similar scope. The system will provide reports of general project status and progress. It will focus attention on problems that could cause cost overruns, schedule delays, or difficulties in meeting technical objectives, so that timely and appropriate action may be taken to resolve the problem. The essence of the system is outlined in the following paragraphs.

6.1.1 INTRAPROJECT REVIEW

The foundation of the review system is the continual series of informal meetings among the various personnel assigned to the project. Such meetings assure that the day-to-day routine of the project is being executed according to plan and that problems are being brought to the prompt attention of appropriate personnel. These meetings involve

frequent contact between the Project Manager and key personnel and between appropriate project and contractor personnel. These meetings will be supplemented by formal status reviews conducted by the Project Manager at the times of key milestones or approximately every 90 days, as appropriate.

6.1.2 LINE ORGANIZATION REVIEW

Line supervisors in the organizational units providing project support are charged with the responsibility of insuring that the resources of the supporting groups are adequately brought to bear. Discharging this responsibility will involve frequent reviews of subsystems under the cognizance of these units. Representatives of other technical areas will participate in these reviews in order to assure appropriate interface coordination. This line organization responsibility will also involve periodic review of status with the Project Manager and/or higher line management echelons, as appropriate.

The prime responsibility for review and monitoring of this project lies with the assigned LRC Division. LRC management will, by periodic review, insure that the Project Manager is properly discharging his responsibilities. Execution of this responsibility will involve periodic, informal reviews of project status with the Project.

Manager and periodic formal project reviews. Many of these informal reviews will supersede the formal project reviews normally conducted by the Project Manager and will include independent technical specialists, as appropriate.

6.1.3 CENTER MANAGEMENT REVIEW

Center management will meet periodically with the Project Manager and other personnel as appropriate to informally review project status.

Special committees established by Center management are delegated responsibility to review project status and provide written assessments to the Director. The Project Coordination Committee meets monthly to assess the status of all flight projects regarding schedules, funding, and technical progress. Technical review, in depth, of all flight projects is provided by special committees. In the case of Project SUAS, this responsibility has been assigned to the ____________________ Steering Committee which will meet at appropriate intervals. A committee of specialists will conduct a critical design review prior to final design.

Special status reviews will be held for and at the request of Center management whenever any of the reporting and review system elements indicate a need for such review.

6.1.4 PROJECT COORDINATION MEETING

Project coordination meetings will be called by the Project Manager as required to resolve interface problems in the various subsystem areas. The Project Manager will specify the individuals whose attendance is required, depending upon the purpose of the meeting. The Headquarters Program Manager will be informed of the technical, operational, and financial status of the project by informal verbal communication with the LRC Project Manager, and by written communication through normal administrative channels. All LRC commitments will be handled through the LRC Director's office.

6.1.5 ENVIRONMENTAL TEST COMMITTEE

A Payload Environmental Test Committee will be established by the Project Manager, and will be responsible for acceptance or rejection of environmental test results. In addition, the committee will review the test program periodically for the purpose of recommending changes in the program or test levels dictated by experience or new information. The committee will also be responsible for determining the disposition or requirements for additional testing of models that fail to qualify under environmental testing.

6.1.6 DESIGN REVIEW BOARD

A design review board will conduct reviews of the design. Areas to be reviewed will include ground equipment, payload, data acquisition and tracking system, launch vehicle, and systems reliability. Members of the design review group will attend design reviews conducted by the contractor. The board will submit a report certifying the design on completion of detail design.

6.2 PROJECT REPORTING

6.2.1 PROJECT DEVELOPMENT PLAN (PDP)

This document records LRC's plan for accomplishing the SUAS project. The PDP is a dynamic document which requires modification as the project progresses, and as decisions are made which change the material contained in the PDP. The Project Manager is responsible for prompt issuance of revisions and page changes necessary to maintain the currency and adequacy of the PDP.

Every 6 months (July or December), the PDP will be revised to summarize the results to date. This revision will describe the accomplishments of the project.

The final version of the PDP, including the revision incorporating results of the latest launch covered by the PDP, will become the permanent record of the project..

6.2.2 USE OF NASA/PERT SYSTEM

A key element in the LRC project management process and in the management information system is the use of the NASA/PERT and Companion Cost System. Meetings held to update the NASA/PERT scheduling serve as a forum for key project personnel to review project status, progress, and problems. From this review, NASA/PERT reports are generated for use by project personnel, key Center personnel, and Center management as an aid in executing project management responsibilities. NASA/PERT reports on this project will also be transmitted to OSSA to aid in execution of Headquarters Program responsibility.

The main elements of the NASA/PERT and Companion Cost reporting system are summarized in the following list. The schedule of report submittals to OSSA is also noted.

(a) Detailed PERT network and computer output: submitted as initially formulated and after major revisions.

(b) Master schedules (similar to Figure VIII-a of the NASA/PERT Handbook and including a trend chart for final systems checkout): biweekly.

(c) Project Manager's narrative analysis (as per Figure IX-e of the NASA/PERT Handbook): biweekly.

(d) Master Financial Plan (as per Figure VIII-d of the NASA/PERT Handbook and including a cost-to-completion trend curve similar to that of Figure IX-c): monthly.

(e) Financial Management Report: monthly.

(f) Trend Chart for Major Subsystems: monthly.

6.2.3 BUDGET REPORTS AND REVIEWS

The Project Manager will be responsible for preparing quarterly estimates of resources requirements on his project. These estimates will be prepared during the life of the project. Twice a year, the Project Manager will comprehensively review the status of his project based on local calls in March and September, and will recommend appropriate revisions to the currently authorized budget.

The regular scheduled resource estimates and financial reports will not relieve the Project Manager of responsibility for submitting recommendations for changes in resources allocation whenever he feels that those resources are inconsistent or incompatible with the progress or ultimate success of the project.

6.2.4 CONTRACTOR PROGRESS REPORT

Contractors will submit a monthly progress report to the Project Manager. These reports will review technical status and indicate progress in achieving scheduled project milestones.

6.2.5 OTHER REPORTS

As has been noted in other sections of this PDP, reports other than those generated by use of the NASA/PERT are available for management of the project. Also, information on the project is included in other reports submitted by the Center to Headquarters.

PART VII

PROCUREMENT ARRANGEMENTS

7. PROCUREMENT APPROACH

The SUAS system procurement will be divided into four phases, namely:

(a) Research and Development

(b) Manufacture

(c) Site acquisition and construction

(d) Crew training.

The SUAS Project will use contract services for preparing detailed procurement specifications for each of the procurements.

In the Research and Development Phase, it is planned to use a systems type of procurement with a single contractor responsible for the entire R&D procurement package. Since the Data Acquisition and Tracking Subsystem is the most significant subsystem, it is anticipated that a contractor, qualified to build the DA&T subsystem, will

be selected as the systems contractor. The systems contractor, with the approval of the Project Manager, will select the launcher and payload subsystems. In addition to his subsystem R&D responsibilities, the systems contractor will be responsible for costs, schedules and system integration. An additional contractor or contractors may be selected to provide support in the areas of system reliability/maintainability and safety monitoring.

Detailed planning for the manufacture of site equipment, site acquisition and crew training will be developed during the R&D phase.

7.1 PROCUREMENT PLAN

Detailed procurement planning and actual execution of contracts pertinent to this project will be accomplished in accordance with NASA Procurement Regulation 18-3.8. This includes preparation of a procurement plan, issuance of request for proposals, contractors proposals and negotiation and preparation of contracts.

7.2 PROCUREMENT RESPONSIBILITY

In accordance with standard LRC project management procedures, procurement responsibility for this project is assigned to the LRC Procurement Division. Technical monitoring of the procurements will

be the responsibility of the SUAS Project technical personnel. Figure VII-1 is a detailed breakdown of responsibilities for the SUAS Project.

7.3 PROCUREMENT SCHEDULE

The procurement milestones are shown in the initial master schedule in Figure VIII-1.

Element	Contractor or Agency	Procurement Center	Technical Monitoring	Contract Admin.	
				Prime	Sub
<u>R&D</u>					
Data Acquisition & Tracking					
Launch Vehicle					
Payload					
Site Design					
<u>Production</u>					
Data Acquisition & Tracking					
Launch Vehicle					
Payload					
Site Acquisition & Construction					
<u>Personnel</u>					
Employment					
Training					

Figure VII-1. Procurement Management Arrangements

PART VIII

SCHEDULES

8. MASTER SCHEDULE

The project master schedule and the initial milestones are shown in Figure VIII-1. Additional milestones will be established as the R&D phase progresses.

8.2 REPORT SCHEDULE

A detailed report schedule will be developed in accordance with the OSSA/OART Project Management Information and Control System (MICS) (NHB 2340.2) and the NASA/PERT and Companion Cost System (NPC 101).

PART IX

RESOURCE REQUIREMENTS

9. RESOURCES

Resource requirements in terms of manpower, facilities, and funding have been estimated and are included in this section.

9.1 MANPOWER REQUIREMENTS

The SUAS manpower requirements for LRC project management is estimated to peak at about 10 professionals. It is anticipated that project staff requirements will be:

	Manpower
FY 1	6
FY 2	6
FY 3	9
FY 4	10
FY 5	10
FY 6	10
FY 7	8
FY 8	2
FY 9	2
FY10	2

Support to the Project Manager in performing Center work will be provided by various Center organizations. It is estimated that this will involve a 3 to 5 man-year effort.

Manpower for the development, production, installation and test of the SUAS system will be provided by contractors.

9.2 FACILITIES REQUIREMENTS

The research phase of this product, which is the responsibility of LRC, will require the construction and operation of 1 or several launch sites.

The operation/SUAS program will require 101 supporting sites (1 training plus 100 operational). Since these sites are small, it is anticipated that many can be accommodated at existing government facilities. Therefore, this section will be amended as soon as the system launching sites are selected. Requirements are shown in the following table.

Fiscal Year

	1	2	3	4	5	6	7	8	9	etc.
Sites Completed & Operational	1*	41	81	101	101	101	101	101	101	101

*Training Site - Wallops Station

9.3 Funding

The funding requirements for the SUAS Project are estimated as follows:

ANNUAL FUNDING REQUIREMENTS ($1,000)

	FY1	FY2	FY3	FY4	FY5	FY6	FY7	FY8	FY9	FY10	FY11	FY12	FY13
R&D													
Data Acquisition & Tracking	2,650	11,250	8,600										
Launch System	142	706	565										
Payload	101	502	402										
TOTAL R&D	2,893	12,458	9,567										
PRODUCTION													
DA&T			33,415	32,420	16,210								
Launch System			2,837	2,768	1,384								
Payload			687	680	340								
Launch Site				8,934	8,716								
Total Production			36,939	44,802	26,650								
OPERATIONS (average number, crews/sites)						2[illegible]/15	6/56	99/94	101/101				
Personnel					50	1,929	4,897	7,345	7,493	7,493	7,493	7,493	7,493
Maintenance and Utilities					10	24	87	145	156	156	156	156	156
Spares DA&T						416	1,528	2,603	2,800	2,800	2,800	2,800	2,800
Launch Vehicle						918	3,427	5,752	6,181	6,181	6,181	6,181	6,181
Payload						442	1,122	1,675	1,717	1,717	1,717	1,717	1,717
Total Operations					60	3,729	11,061	17,520	18,347	18,347	18,347	18,347	18,347
TOTAL YEAR ($1,000)	2,893	12,458	46,506	44,802	26,710	3,729	11,061	17,520	18,347	18,347	18,347	18,347	18,347

PART X

OPERATING PLAN

10. GENERAL

The detailed operating plan, showing network and site operations, will be developed in conjunction with the agency(s) assigned operational control and/or users of the system. This plan will show the start-up period and normal operations of the system as well as define the interfaces between other meteorological systems.

PART XI

PROJECT RESULTS

11. R&D PHASE

The procedure by which the experimental portion of this program will be analyzed and data reduced and disseminated in general will conform to past practices.

The Project Manager will arrange, through the experiments coordinator, for the acquisition of experimental data using NASA or other ground stations.

11.1 LONG-TERM RESULTS

It is anticipated that the long-term results of this program will be a better understanding of the behavior of the earth's atmosphere. This knowledge will be translated into tangible benefits for mankind such as:

(a) Long-term weather forecasting

(b) Weather modification

(c) Safer and more economical air travel

(d) Improved space reentry.